areas, shaft, coal chute and dust collector areas, bucket and transfer houses, and mobile equipment maintenance areas) and maintenance areas. Other fire locations included coal silos, loading docks, refuse piles, abandoned and coal pit areas, dust collectors, baghouses, crushers and beltline areas, and facilities. The largest number of fires throughout the periods occurred at mobile equipment working areas (table 25).

Burning Materials

Table 26 shows the number of fires by burning material and time period. The material most often involved was hydraulic fluid/fuel, followed by oxyfuel/grease/clothing, flammable liquids, coal and coal dust, and straw and refuse. Other burning materials included electrical systems, batteries, collector rings and breakers, dust collectors, baghouses, and furnaces. Belts, idlers and pulleys, air compressors, transmission oil, facilities and contents, and natural gas and chemicals also burned during fires. The largest number of fires involved hydraulic fluid/fuel throughout the periods (table 26).

Fire Injuries

Table 27 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location during 1990–1999. Overall, there were 93 injuries and 1 fatality caused by 94 fires.

The greatest number of fire injuries occurred in 1990 (19 injuries caused by 19 fires) and 1991 (13 injuries and 1 fatality caused by 14 fires). The ignition sources that caused most of the fire injuries were flame cutting/welding spark/slag/flames and hydraulic fluid/fuel sprayed onto equipment hot surfaces. These were followed by flammable liquid on hot surfaces and by heat sources and pressurized can explosions. Other ignition sources were engine/mechanical malfunctions/friction and conveyor belt friction. The equipment most often involved included oxyfuel torches, mobile equipment, heaters, maintenance equipment, dust collectors and samplers, and beltlines. The locations where most of the fire injuries occurred were flame cutting/welding and mobile equipment working areas. Other fire locations were maintenance, dust collector, and beltline areas.

The fire fatality in Montana in 1991 was caused by a flashback accompanied by a gas explosion that engulfed the mechanic who was hosing down a coal chute smoldering fire. The smoldering of coal was due to undetected hot slag produced during flame cutting/welding operations [MSHA 1991b].

COAL PREPARATION PLANT FIRES

Table 28 and figure 10 show the number of fires and fire injuries for coal preparation plants by state during 1990–1999. Table 28 also shows the risk rates, employees' working hours, and lost workdays by state. For coal preparation plants, 91 fires occurred in 11 states during 1990–1999. Twenty-three of those fires caused 25 injuries (the yearly average was 9.1 fires and 2.5 injuries). Ten fires and eight injuries involved contractors. The Ewhr value was 241 × 10^6 hr (Irr = 0.021), and the LWD value was 198.

Pennsylvania had the most fires (24 fires and 4 injuries), whereas West Virginia (22 fires and 7 injuries) and Kentucky (22 fires and 7 injuries) had the most fire injuries. Among these states, Kentucky had the highest injury risk rate value (Irr = 0.025).

Table 29, partly illustrated in figure 11, shows the number of fires, fire injuries, risk rates, employees' working hours, and lost workdays by time period. The number of fires decreased during most of the periods (an increase is seen only during the last period). The number of fire injuries show a decrease followed by an increase during the periods, accompanied by a decline in employees' working hours throughout the periods. The Irr values follow patterns similar to those shown by the injury values (see table 29 and figure 11).

Tables 30–35 show the number of fires by ignition source, method of detection and suppression, equipment involved, location, and burning material by time period. Figure 12 shows the major variables during 1990–1999. Table 36 shows the fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location.

Ignition Source

The number of fires and fire injuries by ignition source and time period is show in tables 30 and 36. The leading source was spontaneous combustion/hot coal (24 fires or 26%). This was followed by flame cutting/welding spark/slag/flames (15 fires or 17% with 8 injuries), hydraulic fluid/fuel sprayed onto equipment hot surfaces (10 fires or 11% with 6 injuries), and conveyor belt friction (9 fires or 10% with 1 injury). The flame cutting/welding spark/slag/flame ignition source caused fires usually involving welders' clothing or oxyfuel/grease (grease embedded in the equipment's mechanical components). However, in one instance undetected hot slag caused a storage facility fire. Other ignition sources were electrical short/arcing (nine fires), flammable liquid/refueling fuel on hot surfaces (six fires), engine/mechanical malfunctions/friction (three fires), overheated oil (two fires), and a chemical explosion (one fire). Eight ignition sources were unknown. The spontaneous combustion/hot coal fires were detected long after the fires had started due to lack of continuous and early combustion gas/smoke detection systems. Two of the mobile equipment hydraulic fluid/fuel fires became large fires, which at times required fire brigade and fire department interventions. In two instances the cab was suddenly engulfed in flames, forcing the operators to exit under hazardous conditions, probably due to the ignition of flammable vapors and mists that penetrated the cab. Of note is that most of the hydraulic fluid/fuel fires were caused when hydraulic fluids sprayed onto equipment hot surfaces; subsequently, these fires involved the fuel lines.

During the first, third, fourth, and fifth periods, the largest number of fires were caused by spontaneous combustion/hot coal. During the second period, the largest number of fires were caused by spontaneous combustion/hot coal and by flame cutting/welding spark/slag/flames (see table 30).

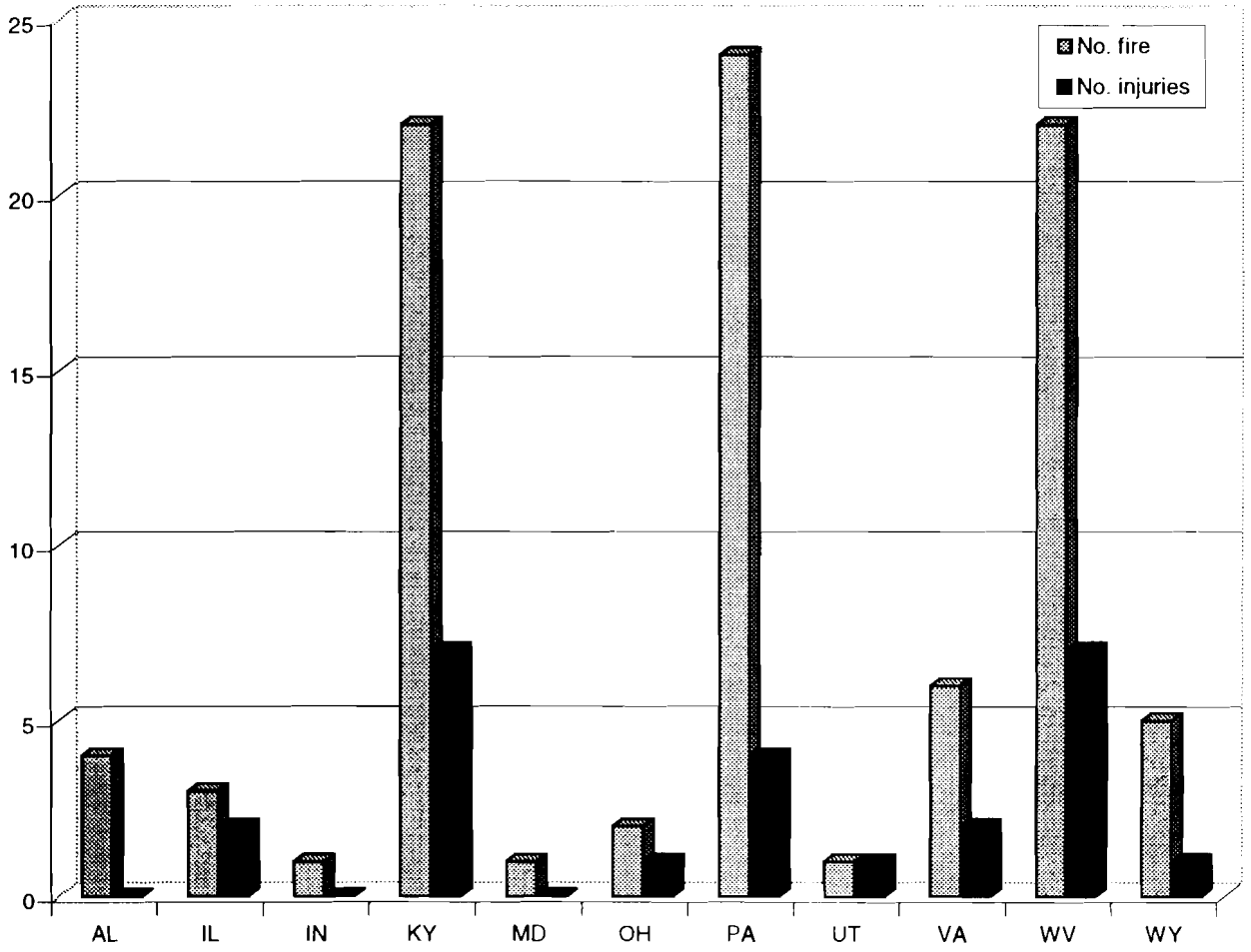

Figure 10.—Number of fires and fire injuries for coal preparation plants by state, 1990–1999.

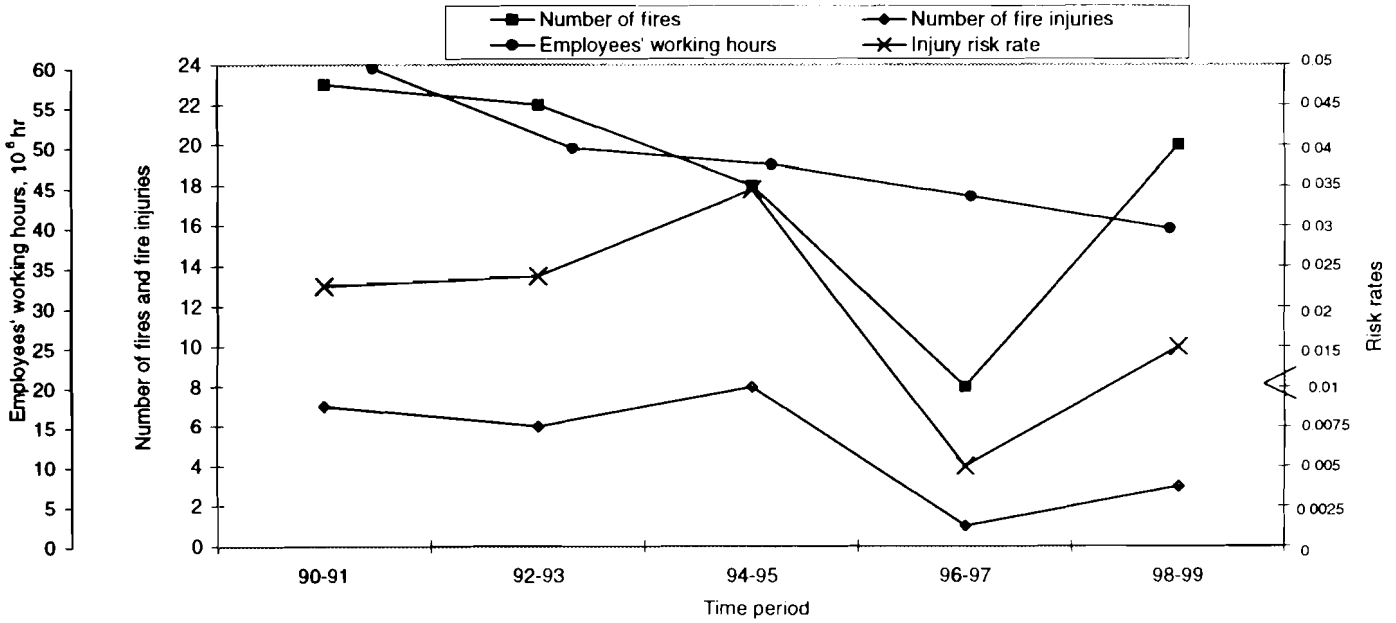

Figure 11.—Number of fires, fire injuries, and risk rates for coal preparation plants by time period and employees' working hours, 1990–1999.

Table 28.—Number of fires, fire injuries, and risk rates for coal preparation plants by state, employees' working hours, and lost workdays, 1990–1999

State[1]	No. fires[1]	No. injuries[1]	LWD[2]	Ewhr,[2] 10^6 hr	Irr[3]
Alabama	4	—	—	11	—
Illinois	3	2	14	15	0.027
Indiana	1	—	—	8.4	—
Kentucky	22	7	83	56	0.025
Maryland	1	—	—	1	—
Ohio	2	1	7	12.5	0.016
Pennsylvania	24	4	60	34.4	0.023
Utah	1	1	—	2.1	0.095
Virginia	6	2	—	21.5	0.019
West Virginia	22	7	34	59.5	0.024
Wyoming	5	1	—	4.1	0.049
Other states	—	—	—	15.3	—
Total	91	25	198	241	[3]0.021

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Coal Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

Table 29.—Number of fires, fire injuries, and risk rates for coal preparation plants by time period, employees' working hours, and lost workdays, 1990–1999

	Time period					
	90-91	92-93	94-95	96-97	98-99	90-99
Number of fires[1]	23	22	18	8	20	91
Number of fire injuries[1]	7	6	8	1	3	25
LWD[2]	116	19	37	—	26	198
Ewhr,[2] 10^6 hr	60	50	48	44	39	241
Irr[3]	0.023	0.024	0.033	0.005	0.016	[3]0.021

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Coal Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

Table 30.—Number of fires for coal preparation plants by ignition source and time period, 1990–1999

Ignition source	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Heat source	1	—	2	—	1	4
Conveyor belt friction	1	2	2	—	4	9
Flame cutting/welding spark/slag/flame[1]	4	6	2	1	2	15
Chemical explosion	—	—	—	1	—	1
Spontaneous combustion/hot coal	5	6	4	4	5	24
Flammable liquid/refueling fuel on hot surfaces/ explosion	3	1	1	—	1	6
Electrical short/arcing[2]	2	4	1	—	2	9
Overheated oil	—	1	—	—	1	2
Engine/mechanical malfunctions/friction	1	—	1	1	—	3
Hydraulic fluid/fuel on equipment hot surfaces	3	2	2	1	2	10
Unknown	3	—	3	—	2	8
Total	23	22	18	8	20	91

[1]This source caused fires usually involving welders' clothing or oxyfuel/grease. However, in at least one instance undetected hot slag caused a storage facility fire.
[2]On one occasion this source caused a coal dust explosion in a dust collector.

Table 31.—Number of fires for coal preparation plants by method of detection and time period, 1990–1999

Method of detection	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Visual:						
Flames/flash fires	8	3	3	2	4	20
Smoke	2	4	4	1	3	14
Sparks	1	5	1	1	1	9
Smoldering	—	—	—	—	1	1
Late smoke detection	6	9	6	3	8	32
Dim lights	—	—	—	—	1	1
Explosion	1	—	—	1	—	2
Popping sound	1	—	—	—	—	1
Undetected	2	1	3	—	1	7
Touched hot spots	1	—	1	—	—	2
Other	—	—	—	—	1	1
Total	23	22	18	8	20	91

Table 32.—Number of fires for coal preparation plants by suppression method and time period, 1990–1999

Suppression method	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Manual/FE[1]	3	5	4	1	1	14
FE-foam/water/dry chemical powder	8	7	2	1	8	26
Water	7	3	4	1	5	20
Coal spread-water-compaction removal[2]	2	5	4	3	4	18
Destroyed/heavily damaged[3]	3	2	4	2	2	13
Total	23	22	18	8	20	91

FE Portable fire extinguisher.

[1]Methods used by welders to extinguish clothing or oxyfuel/grease fires.

[2]Methods used to extinguish spontaneous combustion/hot coal fires. In one case, a CO_2 permanent fire extinguishment system was used.

[3]Due to failure of other firefighting methods, late fire detection, or undetected fires.

Table 33.—Number of fires for coal preparation plants by equipment involved and time period, 1990–1999

Equipment	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Electrical control/power system	2	3	1	—	1	7
Oxyfuel torch	4	6	2	1	2	15
Heater/maintenance equipment	2	—	3	—	—	5
Airlock gate	1	—	—	—	—	1
Dust sampler/collector/dryer/washer	4	—	—	1	1	6
Beltline/drive/pulley	1	3	2	—	5	11
Facility	1	—	3	—	1	5
Chemical tank	—	—	—	1	—	1
Hopper	—	—	—	—	2	2
Mobile equipment[1]	5	4	3	2	3	17
Air compressor	—	1	—	—	—	1
Other[2]	3	5	4	3	5	20
Total	23	22	18	8	20	91

[1]Includes loader, dozer, and haulage/utility trucks.

[2]Includes nonequipment (mostly coal piles).

Table 34.—Number of fires for coal preparation plants by location and time period, 1990–1999

Location	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Flame cutting/welding areas[1]	4	6	2	1	2	15
Beltline/rail dump areas	3	2	3	—	4	12
Coal silos/stock pile/coal feeder	4	5	5	4	5	23
Power station	—	1	—	—	1	2
Maintenance areas	3	1	2	—	1	7
Thermal dryer/dust collector/washer/hopper areas	3	2	—	—	2	7
Airlock gates	1	1	—	—	—	2
Charging station	—	—	—	1	—	1
Mobile equipment working areas[2]	3	3	3	2	3	14
Facility area	2	1	3	—	2	8
Total	23	22	18	8	20	91

[1]Includes packing material building, plastic material storage, coal bypasses, loadout facilities, raw coal silos, drawoff tunnels, coal feeders, shops, coal hoppers, and mobile equipment maintenance areas.
[2]Includes loading and haulage areas.

Table 35.—Number of fires for coal preparation plants by burning material and time period, 1990–1999

Burning material	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Oxyfuel/grease/clothing	2	4	1	1	1	9
Alcohol/chemicals	1	—	—	1	—	2
Flammable liquids/oil/grease	2	2	3	—	1	8
Belt/drive/pulley	3	3	3	—	4	13
Facility/content	1	—	3	—	1	5
Coal/coal dust/wood/insulation/rubber tires/ packing materials	8	7	7	4	7	33
Electrical systems/wires/cables	1	4	—	—	2	7
Hydraulic fluid/fuel	3	2	1	1	3	10
Equipment mechanical components	2	—	—	1	1	4
Total	23	22	18	8	20	91

Table 36.—Number of fire injuries per number of fires causing injuries and total fires at coal preparation plants by year, ignition source, equipment involved, and location, 1990–1999

Year	No. fires causing injuries	No. total fires	No. fire injuries	Ignition source	Equipment	Location
1990	2	11	3	Refueling fuel on hot surfaces	Pump/heater	Pump housing/maintenance areas.
	1	—	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1991	1	12	1	Electrical short/arcing-coal dust explosion	Dust sampler	Dust collector area.
	1		1	Heat source	Heater	Maintenance area.
	1	—	1	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Loading area.
1992	3	11	3	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	1	—	1	Electrical short-flammable liquid	Thermal dryer	Dryer area.
1993	1	11	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	1	—	1	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Loading area.
1994	1	10	1	Heat source-flammable liquid	Heater	Maintenance area.
	1	—	1	Refueling fuel on hot surfaces	Maintenance equipment	Maintenance area.
	1	—	1	Conveyor belt friction	Beltline	Beltline area.
1995	1	8	1	Flame cutting welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	2	—	3	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Loading/haulage areas.
	1	—	1	Mechanical malfunction	Mobile equipment[2]	Haulage area.
1996	1	5	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1997	—	3	—	—	—	—
1998	1	10	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1999	1	10	1	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Loading area.
	1		1	Heat source-flammable liquid	Thermal dryer	Dryer area.
Total	23	91	25			

[1]Includes loadout facilities, sump and coal feeder areas, shops, packing material building, and plastic material storage.
[2]Includes loaders and trucks.

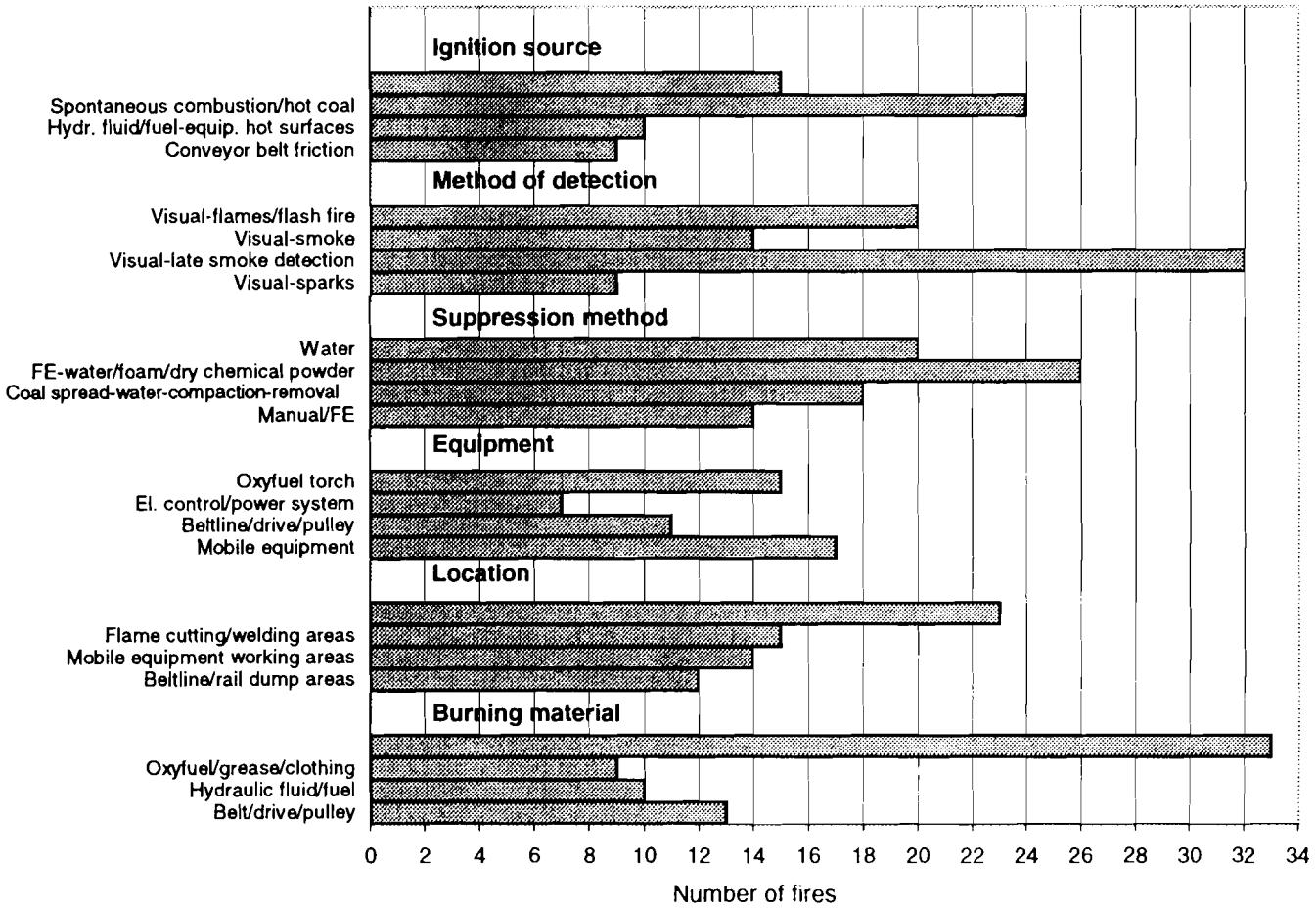

Figure 12.—Major variables for coal preparation plant fires, 1990–1999. (FE = portable fire extinguisher)

Method of Detection

Table 31 shows the number of fires by method of detection and time period. The most frequent method was miners who saw smoke long after the fires had started, followed by operators who saw the fires when they started as flames/flash fires, miners who saw smoke shortly after the fire had started, and welders who saw sparks. Other methods of detection were miners who touched hot spots, miners who saw smoldering of coal or heard an explosion, and operators who heard a popping sound or saw dimming of equipment lights. In one instance, a coal sampler detected a coal silo smoldering fire. Seven fires were undetected.

During the first period, the largest number of fires were detected when they started as flames/flash fires. During subsequent periods, the largest number of fires were detected late by smoke (see table 31).

Suppression Method

Table 32 shows the number of fires by suppression method and time period. The most common methods were water alone and coal spread, water, compaction, and removal. These were followed by portable fire extinguishers, foam, dry chemical powder and water, manual techniques with or without portable fire extinguishers, and dry chemical and water alone. In one instance, a permanent CO_2 fire-extinguishing system was used to put out a coal silo smoldering fire. None of the mobile equipment involved in fires had machine fire suppression systems. Most of the hydraulic fluid/fuel fires became large fires, which in one instance required a fire brigade and fire department intervention because of the continuous flow of fluid/fuel from the pumps due to engine shutoff failure, lack of an emergency hydraulic line drainage system (the flow of pressurized fluids entrapped in the lines was not affected by the engine shutoff operation), difficulty in activating available emergency systems at ground level, or lack of effective and rapid local firefighting response capabilities. (Fire-resistant hydraulic fluid is not required for equipment use at surface coal operations.)

Fire brigades and fire departments (required on at least nine occasions) fought the mobile equipment fires and other large fires with foam, dry chemical powder, and water. However, 13 fires destroyed or heavily damaged equipment (including four pieces of mobile equipment) because of failure of other firefighting methods, late fire detection, undetected fires, or fire size.

During the first, second, and fifth periods, the largest number of fires were suppressed with portable fire extinguishers, foam, dry chemical powder, and water. During the third period, the largest number of fires were extinguished by coal spread, water,

compaction, and removal; manually with or without portable fire extinguishers; and water alone. During the fourth period, the largest number of fires were extinguished by coal spread, water, compaction, and removal (see table 32).

Equipment Involved

Table 33 shows the number of fires by equipment involved and time period. The equipment most often involved included mobile equipment (loaders, dozers, and trucks); oxyfuel torches; and beltlines, drives, and pulleys. Other equipment included electrical control and power systems, dust collectors and samplers, dryers and washers, heaters and maintenance equipment, hoppers, airlock gates, chemical tanks, and air compressors.

During the first period, the largest number of fires involved mobile equipment. During the second period, the largest number of fires involved oxyfuel torches. During the third period, the largest number of fires involved heaters, maintenance equipment, facilities, and mobile equipment. During the fourth and fifth periods, the largest number of fires involved mobile equipment (see table 33).

Location

Table 34 shows the number of fires by location and time period. The most common locations were coal silos, stockpile, and coal feeder areas and flame cutting/welding areas (at packing material buildings, plastic material storage, coal bypasses, loadout facilities, raw coal silos, drawoff tunnels, coal feeders, shops, coal hoppers, and mobile equipment maintenance areas). Other fire locations were mobile equipment working areas (loading and haulage areas), beltline and rail dump areas, facilities, and maintenance areas. Also affected by fires were thermal dryer, dust collector, washer, and hopper areas; power stations; airlock gates; and charging stations.

During the first and second periods, the largest number of fires occurred at flame cutting/welding areas. During the third, fourth, and fifth periods, the largest number of fires occurred at coal silo, feeder, and stockpile areas (see table 34).

Burning Materials

Table 35 shows the number of fires by burning material and time period. The materials most often involved were coal and coal dust, insulation material, rubber tires, wood, and packing materials, followed by belts, drives, and pulleys and hydraulic fluid/fuel. Other burning materials were flammable liquids, oil/grease, oxyfuel/grease/clothing, electrical systems, wires and cables, facilities and contents, equipment mechanical components, and alcohol and chemicals. Throughout the periods the largest number of fires involved coal, coal dust, wood, insulation, rubber tires, and packing materials (table 35).

Fire Injuries

Table 36 shows the number of fire injuries, number of fires causing injuries, and total fires by year, ignition source, equipment involved, and location during 1990–1999. Overall, there were 25 injuries caused by 23 fires.

The greatest number of fire injuries occurred in 1995 (five injuries caused by four fires) and 1992 (four injuries caused by four fires). The ignition sources that caused most of the fire injuries were flame cutting/welding spark/slag/flames, hydraulic fluid/fuel sprayed onto equipment hot surfaces, and flammable liquid/refueling fuel on hot surfaces. Other ignition sources were heat sources, mechanical malfunctions, electrical short/arcing and coal dust explosion, and conveyor belt friction. The equipment most often involved included oxyfuel torches, mobile equipment, heaters, maintenance equipment, dust collectors and samplers, pumps, and beltlines. The fire locations where most of the fire injuries occurred were flame cutting/welding areas and mobile equipment working areas. Other fire locations were maintenance areas, dust collector areas, thermal dryer and beltline areas, and pump housings.

SUMMARY OF MAJOR FIRE AND FIRE INJURY FINDINGS FOR ALL COAL MINING CATEGORIES

The major fire and fire injury findings for all coal mining categories for 1990–1999 are reported in tables 37–38. Table 39 and figure 13 show the number of fires, fire injuries, risk rates, employees' working hours, and coal production (underground and surface coal mines only) by time period for all coal mining categories. Table 40 shows major findings (for underground coal mines only) for 1978–1992.

For all coal mining categories, 458 fires occurred during 1990–1999; 157 of those fires caused 164 injuries and 2 fatalities (Ewhr = 2,070 × 10^6 hr, Irr = 0.016; CP (for underground and surface coal mines only) = 10,363 × 10^6 st, Frr = 0.044, LWD = 14,753). Twenty-nine fires and 17 injuries involved contractors.

Sixty-six fires required firefighting interventions by mine rescue teams (25 times in underground mines) and fire brigades and fire departments (at least 41 times at surface coal operations). In all, 51 fires destroyed or heavily damaged equipment (including 16 pieces of mobile equipment) because of failure of other firefighting methods, late fire detection, undetected fires, or fire size. A total of 114 fires were detected late, and 42 fires were undetected. The greatest number of fires and fire injuries occurred at surface coal mines; the highest risk rate values were also calculated for this category.

For all coal operations, the ignition sources that caused the greatest number of fires were flame cutting/welding spark/slag/flames (103 fires or 23% with 69 injuries), hydraulic fluid/fuel sprayed onto equipment hot surfaces (98 fires or 21% with 29 injuries), spontaneous combustion/hot coal (62 fires or 14%), electrical short/arcing (49 fires or 11% with 18 injuries), and conveyor belt friction (31 fires or 7% with 6 injuries).